Infants prefer the faces of strangers or mothers to morphed faces : an uncanny valley between social novelty and familiarity

AUTHOR(S):

Matsuda, Yoshi-Taka; Okamoto, Yoko; Ida, Misako; Okanoya, Kazuo; Myowa-Yamakoshi, Masako

CITATION:

Matsuda, Yoshi-Taka ...[et al]. Infants prefer the faces of strangers or mothers to morphed faces : an uncanny valley between social novelty and familiarity. Biology Letters 2012, 8(5): 725-728

ISSUE DATE:

2012-06-13

URL:

http://hdl.handle.net/2433/156406

Infants prefer the faces of strangers or mothers to morphed faces: an uncanny valley between social novelty and familiarity

Yoshi-Taka Matsuda[1,2,*], Yoko Okamoto[1], Misako Ida[1], Kazuo Okanoya[1,2,3] and Masako Myowa-Yamakoshi[1,4,*]

[1]Okanoya Emotional Information Project, Exploratory Research for Advanced Technology (ERATO), Japan Science and Technology Agency (JST), Saitama, Japan

[2]Emotional Information Joint Research Laboratory, RIKEN Brain Science Institute, Saitama, Japan

[3]Department of Life Sciences, Graduate School of Arts and Sciences, The University of Tokyo, Tokyo, Japan

[4]Graduate School of Education, Kyoto University, Kyoto, Japan

* Authors for correspondence (matsuda@brain.riken.jp, myowa@educ.kyoto-u.ac.jp)

Summary

The “uncanny valley” response is a phenomenon involving the elicitation of a negative feeling and subsequent avoidant behaviour in human adults and infants as a result of viewing very realistic humanlike robots or computer avatars. It is hypothesised that this uncanny feeling occurs because the realistic synthetic characters elicit the concept of “human” but fail to satisfy it. Such violations of our normal expectations regarding social signals generate a feeling of unease. This conflict-induced uncanny valley between mutually exclusive categories (human and synthetic agent) raises a new question: could an uncanny feeling be elicited by other mutually exclusive categories, such as familiarity and novelty? Given that infants prefer both familiarity and novelty in social objects, we address this question as well as the associated developmental profile. Using the morphing technique and a preferential-looking paradigm, we demonstrated uncanny valley responses of infants to faces of mothers (i.e., familiarity) and strangers (i.e., novelty). Furthermore, this effect strengthened with the infant’s age. We excluded the possibility that infants detect and avoid traces of morphing. This conclusion follows from our finding that the infants equally preferred strangers’ faces and the morphed

faces of two strangers. These results indicate that an uncanny valley between familiarity and novelty may accentuate the categorical perception of familiar and novel objects.

Keywords

- Face perception
- Uncanny valley
- Development
- Preferential looking
- Mother
- Stranger

Short title

Uncanny valley between mother and other

1. Introduction

Highly realistic human-looking robots or computer avatars elicit negative feelings in humans [1-3], the so-called "uncanny valley" response [1]. Because this perceptual effect is also observed in nonhuman primate species [4] and human infants at a late developmental stage [5], the response is likely to have both evolutionary and developmental origins. Furthermore, experience with the early and highly selective perception of the faces of conspecifics has been emphasised as an important factor [5]. Once infants learn the prototype, they presumably acquire sufficient perceptual expertise to detect the slight anomalies inherent in realistic but synthetic avatar faces and begin to exhibit the uncanny valley effect because such violations of normal expectations regarding social signals generate a feeling of unease.

This conflict-induced uncanny valley between mutually exclusive categories (human and synthetic agent) raises a new question: could an uncanny valley response be elicited between other categories, such as familiarity and novelty? Although familiarity contradicts novelty in terms of experience, infants prefer both familiarity and novelty in objects [6]. While infants prefer stimuli that they have not previously encountered, such

as novel objects or sounds, they also exhibit preferences for stimuli with which they have extensive prior experience, such as the mother's face and voice [6]. Scientific research has generally identified and investigated these phenomena separately. In the mere exposure effect [7], familiar things are preferred over novel ones. Other studies utilise effects such as dishabituation, in which novel visual objects and places are preferred (e.g., [8]). However, it is unclear whether infants prefer things that assimilate the properties of both familiarity and novelty, that is, objects on the border between the two categories.

We investigate whether an uncanny valley lies between familiarity and novelty for infants, as previously observed for the features of humans and synthetic agents. We further aim to define the developmental profile of this uncanny valley response. For infants, mothers and strangers represent socially familiar and novel objects, respectively. It is known that six-month-old infants prefer to look at both mothers and strangers if they appear successively [9] whereas neural responses of infants differently process the two faces [9, 10]. These findings support the hypothesis that infants prefer both familiarity and novelty in social objects with different

underlying mechanisms. In the study reported here, we examined whether infants prefer faces on the border between mothers and strangers, and we investigated possible changes in such preferences during development. We evaluated infants' preferential viewing of three pairs of faces: mother *vs.* stranger, mother *vs.* intermediate face, and stranger *vs.* intermediate face. Infants in the second half of their first year begin to distinguish their mothers from strangers by their internal facial features and configural information [11] rather than by their hairlines or facial contour, as observed in neonates [12]. Intermediate faces between mothers and strangers were created by a morphing technique with a physical accuracy of 50% mother and 50% stranger faces rather than by recruiting mother-like strangers based on the experimenters' subjective impressions [9].

2. Materials and Methods

Fifty-one infants (21 male, 30 female; ages 6.9 to 13.1 months) were assigned to three groups according to the infant's age: 7-8 months (n = 17, mean = 7.7 months), 9-10 months (n = 20, mean = 9.6 months) and 11-12 months (n = 14, mean = 11.7 months). Six additional infants were excluded from the analysis because they did not complete the experimental protocol.

The infants were held in the lap of a parent and tested in a soundproof room. The parent wore a mask that prevented them from seeing the visual stimuli. In each of six trials, a pair of faces was presented side-by-side on an eye-tracker screen (Tobii X60, Stockholm, Sweden) that recorded the infants' eye movements. Data have been deposited in the Dryad repository: http://dx.doi. org/10.5061/dryad.s7t47.

Coloured photographs of mothers and strangers were taken prior to the experiments. The photographs showed a smiling face, a face with the individual's hair pinned up and the individual's face without glasses. To create intermediate faces, the faces of a mother and a stranger were morphed together using computer software (Sqirlz Morph 2.1: Xiberpix, Solihul, UK, www.xiberpix.com) to produce a new face that

consisted of 50% of the mother's face and 50% of the stranger's face. We used dynamic facial expressions as visual stimuli for infants because Mori (1970) predicted that movement accentuates the uncanny valley effect [1] and because infants are more responsive to moving faces than to static faces [13] (see the electronic supplementary material). The infants saw three different pairs of stimuli: mother *vs.* stranger, mother *vs.* intermediate face, and stranger *vs.* intermediate face. The presentation was repeated twice with photographs of different strangers as the stimuli representing strangers and intermediate faces. Each test trial was presented for ten seconds. Each trial was preceded by a stimulus intended to attract the infant's visual attention. The order of the six test trials as well as the side on which a given face appeared was random and counterbalanced across participants. A mother's face was used as a stranger's face for other participants to furnish a homogeneous set of stimuli in this study. After the experiment, we confirmed with each mother that the strangers whose faces were presented were not acquaintances of her infant.

3. Results

Figure 1a depicts three different types of stimuli: mothers, intermediate faces and strangers (an example). The infants' viewing preferences are shown in figure 1b. The total time spent looking at each stimulus type was averaged across all test trials for each individual and then normalised to calculate proportions. The proportions were transformed with the arcsine function to achieve a normal distribution. A one-way repeated-measures ANOVA for all participants revealed a significant overall effect ($F_{2, 100} = 9.662$, $p < 0.001$, $\eta_p^2 = 0.162$) (figure 1b). Post hoc comparisons with a Bonferroni correction showed that the difference between mothers' faces and intermediate faces was significant, $p < .001$, and that the difference between strangers and intermediate faces was significant, $p < .001$. No significant difference was found between mothers and strangers, $p \sim 1.000$. These results showed that infants have a lower preference for intermediate faces. We next examined developmental changes in this preference. Although 7- to 8-month-old infants did not show a significant difference in their preferences among the stimuli ($F_{2, 32} = 1.207$, $p > 0.100$, $\eta_p^2 = 0.070$), infants at 9-10 months and at 11-12 months showed a significant difference ($F_{2, 38} = 5.179$, $p < 0.010$,

η_p^2 = 0.214; $F_{2, 26}$ = 4.342, p < 0.025, η_p^2 = 0.250, respectively) (figure 1c). The interaction of Age × Stimulus type was not significant (F(4, 96) = .908, p > .400, η_p^2 = .036). This result represents a robust phenomenon occurring in the second half of the first year.

To exclude the possibility that infants detect traces of morphing and avoid intermediate faces, we presented stimuli representing pairs of strangers. One of these faces was that of a stranger, and the other was a morphed face of two different strangers (both stimuli were also dynamic faces) (figure 2a). The time spent looking at the two faces did not differ significantly (t(19) = .205, p > .800, d = .092) in 7- to 12-month-old infants (figure 2b).

4. Discussion

This study is the first to show that infants have a lower preference for intermediate faces between mothers and strangers than the original faces, and that this property is expressed in development. Given that infants prefer both mothers and strangers as socially familiar and novel objects, respectively [9] (also shown in figure 1b), our results indicate that infants' response to intermediate faces as neither familiar nor novel objects. If intermediate faces are recognised as mothers or strangers, infants should show equal increases in the time spent looking, as observed for the faces of mothers and strangers. Rather, infants may perceive intermediate faces in conjunction with an uncomfortable feeling, as shown by the uncanny valley response, the phenomenon whereby very realistic human-looking robots or computer avatars elicit negative feelings in human adults and infants [1, 2, 5] (also shown in nonhuman primates [4]). Infants may avoid these mother-like strangers because the intermediate face elicits the personal aspect of the mother but fails to satisfy it. Such a failure generates feelings of unease because the traits fall beyond the expected spectrum of everyday social experience with mothers.

Alternatively, it is possible that intermediate faces were perceived as lacking in novelty associated with strangers and lacking in any positive feelings with mothers, thereby causing infants to feel a *disinterest*. This explanation, however, seems less probable, as our preliminary observations with adult subjects indicated an uncanny rather than uninterested feeling in reaction to intermediate faces (see the electronic supplementary material). We have yet to reveal for infants whether the lower preference was associated with a feeling of unease or disinterest. Further physiological studies (e.g., skin conductance response or salivary cortisol level) will clarify whether the infant response represents an uncanny or uninterested valley.

Our findings raise interesting questions about the process underlying the emergence of the uncanny valley between social familiarity and novelty and its developmental changes. Two complementary processes are though to underlie the developmental changes: perceptual learning/differentiation of increasingly finer stimulus features [14, 15], and perceptual narrowing [16-18]. These two processes are likely to contribute to development of the perceptual expertise that is required for perception of subtle differences that define the mother's face. The increase observed in

the time spent looking at the mother's face relative to the time spent looking at intermediate faces in infants between 7-8 months and 9-10 months of age suggests that the infants' everyday experience with their mothers and the association of the mother's face with generally positive consequences confer special status on the mother. With experiences, infants gradually become expert at perceiving increasingly fine features of the mother's face. This expertise may be further enhanced by perceptual narrowing, which enables infants to address a more restricted range of stimulus attributes that can now be explored in a more detailed manner.

In conclusion, the current research has demonstrated another type of the uncanny valley between the face of the mother and the face of a stranger for infants, and this phenomenon appears during development. The processes of perceptual learning/differentiation and narrowing as well as the failure of normal expectations linked to the mother's face may underlie the foundation for the emergence of the uncanny valley between the face of the mother and the face of a stranger.

Acknowledgements

This work is supported by funding from the Japan Science and Technology Agency, Exploratory Research for Advanced Technology, Okanoya Emotional Information Project. We thank M. Imafuku, Y. Kumaki, S. Mizugaki and Y. Tanaka for their help conducting experiments, and H. Fukuyama and H. Goto for helpful comments on the manuscript.

References

1. Mori M. 1970 The uncanny valley. *Energy* **7**(4), 33-35.

2. Seyama J., Nagayama R.S. 2007 The Uncanny Valley: Effect of Realism on the Impression of Artificial Human Faces. *Presence-Teleop Virt* **16**(4), 337-351. (doi:10.1162/pres.16.4.337).

3. MacDorman K.F., Green R.D., Ho C.-C., Koch C.T. 2009 Too real for comfort? Uncanny responses to computer generated faces. *Comput Hum Behav* **25**(3), 695-710. (doi:10.1016/j.chb.2008.12.026).

4. Steckenfinger S.A., Ghazanfar A.A. 2009 Monkey visual behavior falls into the uncanny valley. *Proc Natl Acad Sci U S A* **106**(43), 18362-18366. (doi:10.1073/pnas.0910063106).

5. Lewkowicz D.J., Ghazanfar A.A. 2012 The development of the uncanny valley in infants. *Dev Psychobiol* **54**(2), 124-132. (doi:10.1002/dev.20583).

6. Houston-Price C., Nakai S. 2004 Distinguishing novelty and familiarity effects in infant preference procedures. *Infant Behav Dev* **13**(4), 341-348. (doi:10.1002/icd.364).

7. Zajonc R.B. 1968 Attitudinal effects of mere exposure. *J Pers Soc Psychol Monogr Suppl* **9**, 1-27. (doi:10.1037/h0025848).

8. Fantz R.L. 1963 Pattern vision in newborn infants. *Science* **140**, 296-297. (doi:10.1126/science.140.3564.296).

9. de Haan M., Nelson C.A. 1997 Recognition of the Mother's Face by Six-Month-Old Infants: A Neurobehavioral Study. *Child Dev* **68**(2), 187-210. (doi:10.1111/j.1467-8624.1997.tb01935.x).

10. Nakato E., Otsuka Y., Kanazawa S., Yamaguchi M.K., Honda Y., Kakigi R. 2011 I know this face: neural activity during mother's face perception in 7- to 8-month-old infants as investigated by near-infrared spectroscopy. *Early Hum Dev* **87**(1), 1-7. (doi:10.1016/j.earlhumdev.2010.08.030).

11. Nakato E., Kanazawa S., Yamaguhi M.K., Kakigi R. 2009 Configural information in mother's face perception for infants. *J Vision* **9**(8), article 551. (doi:10.1167/9.8.551).

12. Pascalis O., de Schonen S., Morton J., Deruelle C., Fabre-Grenet M. 1995 Mother’s Face Recognition by Neonates: A Replication and an extension. *Infant Behav*

Dev **18**, 79-85. (doi:10.1016/0163-6383(95)90009-8).

13. Wilcox B.M., Clayton F.L. 1968 Infantvisual fixation onmotion pictures ofthehumanface. *J Exp Child Psychol* **6**(1), 22-32. (doi:10.1016/0022-0965(68)90068-4).

14. Gottlieb G. 1991 Experiential canalization of behavioral development: Theory. *Dev Psychol* **27**(1), 4-13. (doi:10.1037/0012-1649.27.1.4).

15. Nelson C.A. 2001 The development and neural bases of face recognition. *Infant Behav Dev* **10**(1-2), 3-18. (doi:10.1002/icd.239).

16. Pascalis O., de Haan M., Nelson C.A. 2002 Is face processing species-specific during the first year of life? *Science* **296**(5571), 1321-1323. (doi:10.1126/science.1070223).

17. Werker J.F., Tees R.C. 2005 Speech perception as a window for understanding plasticity and commitment in language systems of the brain. *Dev Psychobiol* **46**(3), 233-251. (doi:10.1002/dev.20060).

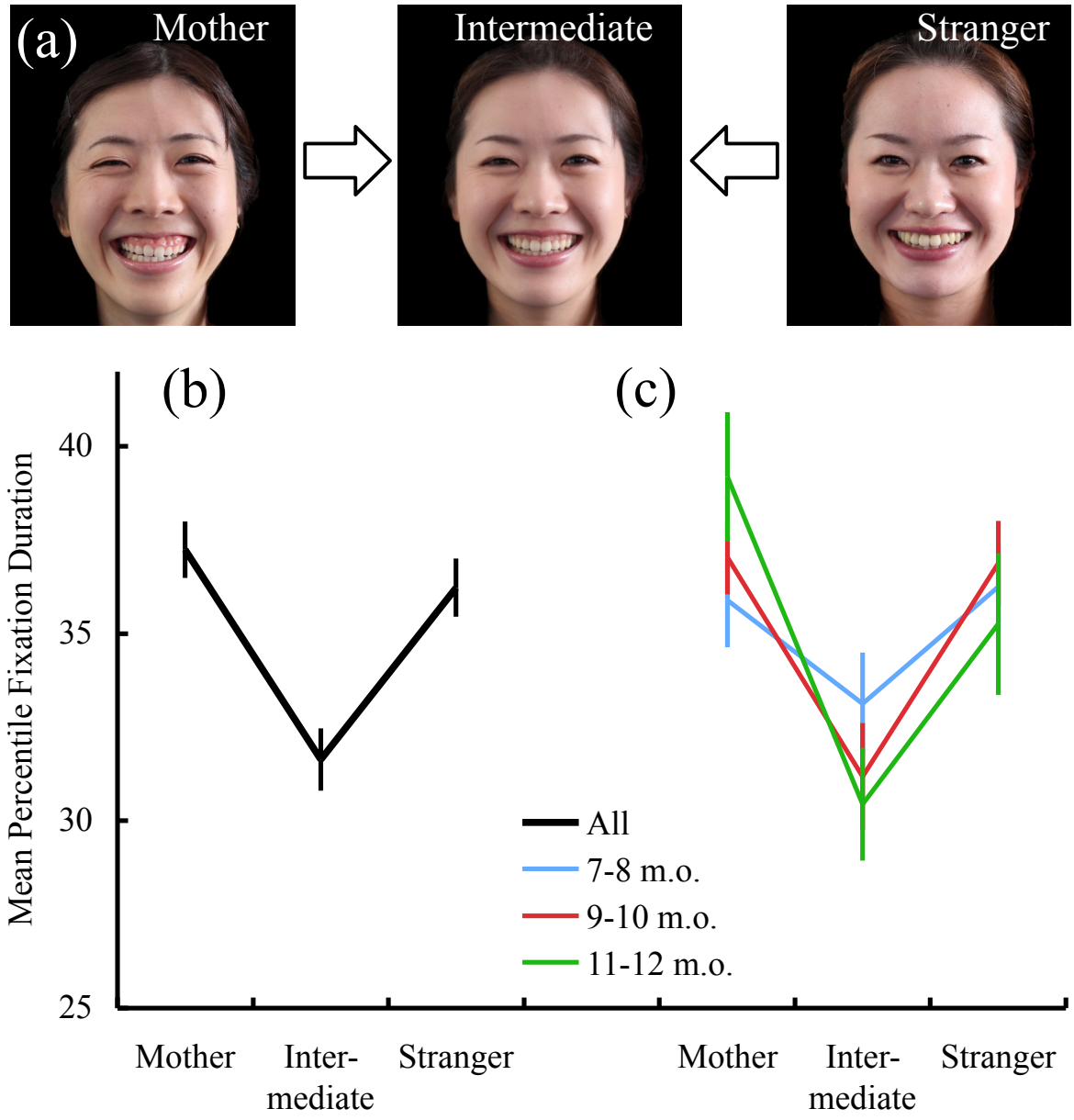
18. Lewkowicz D.J., Ghazanfar A.A. 2009 The emergence of multisensory systems through perceptual narrowing. *Trends Cogn Sci* **13**(11), 470-478.

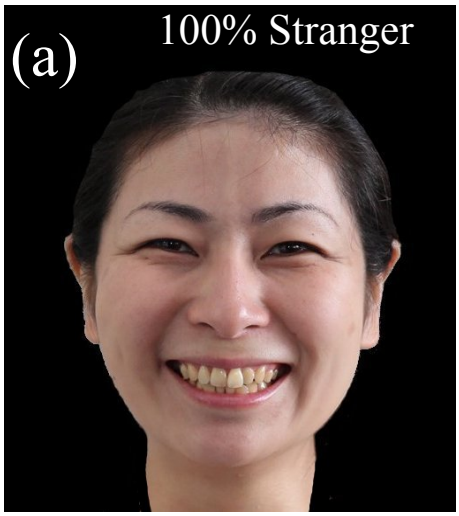
(doi:10.1016/j.tics.2009.08.004).

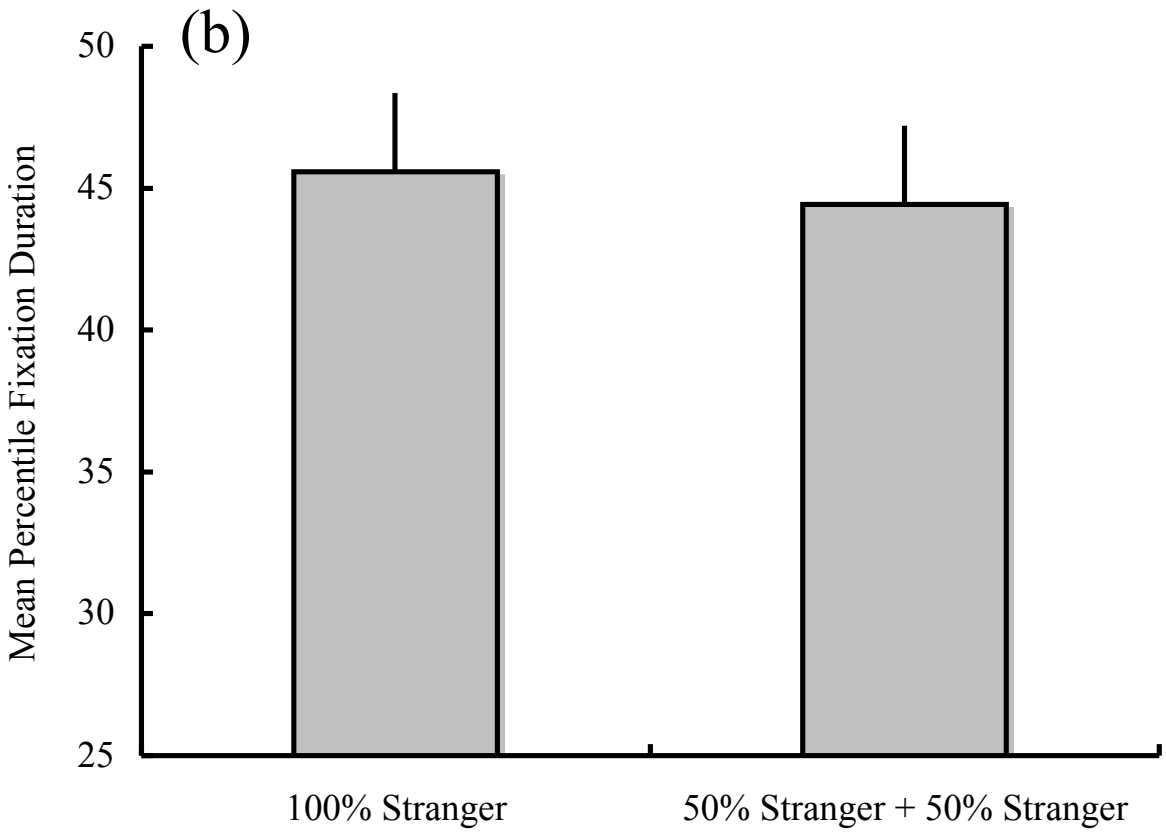
Figure legends

Figure 1. Visual preferences of infants and the development of preferences for different face types. (a) An example of three different types of stimuli: mother's face (left), intermediate face (centre) and stranger's face (right). (b) The mean-percentile fixation duration on each of the face types across infants' ages. (c) Age-dependent differences of fixation durations. Error bars indicate standard errors of the mean. m.o.: month old.

Figure 2. Visual preferences of infants for different face types. (a) An example of two different types of stimuli: 100% stranger (left) and 50%-50% morphed face of different strangers (right). The figure (b) shows the mean-percentile fixation duration on each of the face-types: 100% stranger's face (left) and a 50%-50% morphed face of different strangers (right). Error bars indicate standard errors of the mean.







doi:10.1098/rsbl.2012.0346

Electronic Supplementary Material (ESM)

Title:

Infants prefer the faces of strangers or mothers to morphed faces: an uncanny valley between social novelty and familiarity?

Yoshi-Taka Matsuda*, Yoko Okamoto, Misako Ida, Kazuo Okanoya and Masako Myowa-Yamakoshi*

*To whom correspondence should be addressed. E-mail: matsuda@brain.riken.jp, myowa@educ.kyoto-u.ac.jp

1. Supplementary Material and Methods

We created movie stimuli of smiling faces for mothers, strangers and intermediate faces, which are known as a *dynamic facial expression* or *dynamic face* of happiness [1-5]. Movie stimuli were created in the following way. First, two coloured photographs (neutral and smiling faces) were taken prior to the main experiments for each individual of mothers' and strangers' participants with hair pinned up and their glasses off. Next, between the neutral and smiling expressions for each participant, twenty-four intermediate images in 4% steps were created using computer-morphing techniques (Sqirlz Morph v2.1: Xiberpix, Solihul, UK, www.xiberpix.com). Then, to create a moving clip, a total of 26 images (one neutral image, 24 intermediate images, and the final smiling image) were presented in succession. Each image was presented for 40 ms, and the first and last images were additionally presented for 480 ms; thus each animation clip lasted for 2,000 ms. Each clip was repeated for five times (i.e., ten-second duration) in both the main and control experiments (figure 1 and 2 in the main text). This presentation speed has been found for adults to sufficiently reflect natural changes in the dynamic facial expressions of happiness [5].

doi:10.1098/rsbl.2012.0346

2. Supplementary Results

We presented the mother's face twice for each participant, but different exemplars of the stranger and morphed face. There were possibilities that the repeated presentation of the mothers' faces might have induced a habituation of preference for the infants and shortened the looking time in the second presentation. To address this question, we compared infant looking times between the first and second presentations of their mother's faces. No significant difference was observed for the looking time ($t(50) = 1.270$, $p > 0.200$, $d = 0.196$).

3. Supplementary Discussion

(1) ***Do mother's faces convey familiarity and/or rewarding connotation to infants?***

There is a possibility that the lower preference for faces intermediate between the infants' mothers and strangers was induced by rewarding the association. Indeed, several studies reported that an infant's preference for its mother's face varied with the style of mother-infant interaction [6] and the duration of parental leave for caregiving [7]. These results indicate that familiarity does not necessarily induce an infant's preference for their mother's face. Rather, a face with rewarding connotations might be preferable.

Hence, at least two different monotonic changes might be involved along a mother-stranger morphed continuum. One is a monotonic *fall* in a positive feeling associated with familiar faces. The other is a monotonic *rise* in novelty preferences. Overlaying the two monotonic preference changes with the mutually opposite slope would produce an uncanny (or disinterested) valley around the intermediate faces. Furthermore, the evidence that familiarity and novelty are distinct categories rather than both ends of a single axis was derived from neuroscience studies. Nakato et al. (2011) [8] dissociated familiarity (mother's faces) and novelty (stranger's faces) by revealing distinct representations in an infant's brain. Wilson and Rolls (1983) [9] showed that distinct amygdala neurons respond differently to familiar or novel objects. These results are consistent with our study, in which we showed that familiarity and novelty are distinct categories and that there is a categorical boundary (i.e., a valley) between them.

doi:10.1098/rsbl.2012.0346

This uncanny (or disinterested) valley and its age dependency may suggest the presence and development of neuropsychological mechanisms in infants that accentuate the categorical differences between familiarity and novelty by eliciting the avoidance of (or disinterest in) ambiguity.

(2) *Is it an "uncanny" or "disinterested" valley between the face of the mother and the face of a stranger?*

We did not present direct evidence for negative emotions or feelings in infants associated with the intermediate faces. We should have evaluated physiological measures (e.g., skin conductance response or salivary cortisol level), but this was not the case.

Instead, we conducted a preliminary experiment with *adult* participants (n = 10) to assess subjective feelings in response to the intermediate faces between their parents and strangers. We created intermediate faces with the same method as in the main experiment. Subsequent to the presentation of the intermediate faces (10 seconds), we asked participants three questions. (1) Recognition: we asked them whether or not they recognized *familiar persons* (i.e., parents), whose faces were morphed to create the intermediate faces. All participants correctly recognized their parent's faces in the intermediate faces. (2) Forced choice #1: we asked participants to answer whether they felt a *positive* or *negative* emotion when they perceived the intermediate faces. Seven out of ten participants provided answers of a negative feeling. (3) Forced choice #2: we asked participants to answer whether or not an *uncanny/strange* feeling was induced when they perceived the intermediate faces. Eight out of ten participants provided answers of "yes". Importantly, when intermediate faces consisted of two strangers for participants, they reported neither a negative feeling nor an uncanny/strange feeling against these faces.

Although the results were obtained from our preliminary study of adult participants, these observations might provide an indirect yet supporting evidence for infant's negative/uncanny emotion against intermediate faces between mothers and strangers.

doi:10.1098/rsbl.2012.0346

References

1. Foley E., Rippon G., Thai N.J., Longe O., Senior C. 2012 Dynamic facial expressions evoke distinct activation in the face perception network: a connectivity analysis study. *J. Cogn. Neurosci.* **24**(2), 507-520. (doi:10.1162/jocn_a_00120).

2. Fox C.J., Iaria G., Barton J.J. 2009 Defining the face processing network: optimization of the functional localizer in fMRI. *Hum. Brain Mapp.* **30**(5), 1637-1651. (doi:10.1002/hbm.20630).

3. Kilts C.D., Egan G., Gideon D.A., Ely T.D., Hoffman J.M. 2003 Dissociable neural pathways are involved in the recognition of emotion in static and dynamic facial expressions. *NeuroImage* **18**(1), 156-168. (doi:10.1006/nimg.2002.1323).

4. LaBar K.S., Crupain M.J., Voyvodic J.T., McCarthy G. 2003 Dynamic perception of facial affect and identity in the human brain. *Cereb. Cortex* **13**(10), 1023-1033. (doi:10.1093/cercor/13.10.1023).

5. Sato W., Yoshikawa S. 2004 The dynamic aspects of emotional facial expressions. *Cogn. Emot.* **18**(5), 701-710. (doi:10.1080/02699930341000176).

6. Bigelow A.E., Rochat P. 2006 Two-Month-Old Infants' Sensitivity to Social Contingency in Mother–Infant and Stranger–Infant Interaction. *Infancy* **9**(3), 313-325. (doi:10.1207/s15327078in0903_3).

7. Gredebäck G., Eriksson M., Schmitow C., Laeng B., Stenberg G. 2012 Individual Differences in Face Processing: Infants' Scanning Patterns and Pupil Dilations are Influenced by the Distribution of Parental Leave. *Infancy* **17**(1), 79-101. (doi:10.1111/j.1532-7078.2011.00091.x).

8. Nakato E., Otsuka Y., Kanazawa S., Yamaguchi M.K., Honda Y., Kakigi R. 2011 I know this face: neural activity during mother's face perception in 7- to 8-month-old infants as investigated by near-infrared spectroscopy. *Early Hum. Dev.* **87**(1), 1-7. (doi:10.1016/j.earlhumdev.2010.08.030).

9. Wilson F.A., Rolls E.T. 1993 The effects of stimulus novelty and familiarity on neuronal activity in the amygdala of monkeys performing recognition memory tasks. *Exp. Brain Res.* **93**(3), 367-382. (doi:10.1007/BF00229353).